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ABSTRACT

This document is a summary of the situations of six Asian nations (The People's Republic of China, Japan, Singapore, South Korea, Taiwan, and India) compared to the United States in science and technology education. The paper includes a table of the production of bachelor of science degrees in science and engineering in 1990, comparing the Asian countries as a group with the United States. Graphs of human resources discuss growth in enrollment in higher education, ratio of university enrollments to college age population, and higher education degree data. Degree information is broken down into degrees in the natural sciences and engineering. A chart shows the number and percentage of Asian students from each of the countries in question who study natural sciences or engineering at U.S. universities at the doctoral and bachelor levels. The ratio of science and engineering degrees to total degrees is represented. Expenditures for research and development are compared between the Asian countries and the United States, as are science and engineering personnel. Growth rate in gross domestic product is represented. After the general comparisons, each of the six Asian nations is discussed individually. Implications for the United States include the continuation of Asian countries' use of the U.S. higher education system. Foreign graduate student enrollment in U.S. universities and preference for natural science and engineering degrees will maintain U.S. doctoral program's strong emphasis on natural science and engineering. These nations will challenge the United States, for the personnel educated in U.S. universities for their own high technology economies. (DK)

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Human Resources for Science and Technology: The Asian Region

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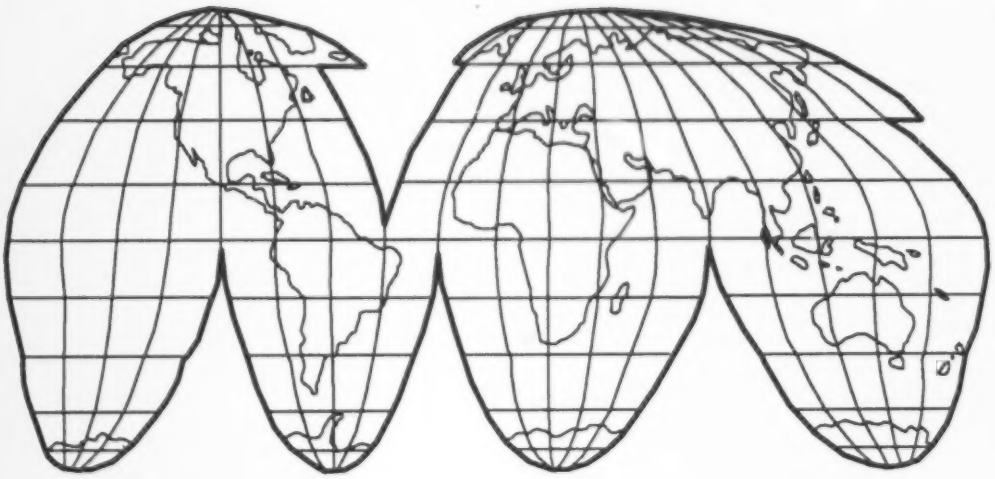

Dr. Jean M. Johnson
National Science Foundation

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Symposium: From Periphery to Center: Higher Education and Science in the Pacific Rim
Atlanta, Georgia
April 15, 1993

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Overview of Human Resources for Science and Engineering

In the last 15 years, the Asia region's production of natural science and engineering (NS&E) degrees has grown dramatically, as have its economy and investment in research and development (R&D), and its attendant need for scientists and engineers (S&E). The countries studied for this research- The People's Republic of China, India, Japan, Singapore, South Korea and Taiwan- are ancient cultures with traditions of scholarship which cannot be adequately described by examining the last 15 years of data. However, data presented in this research on their growth in degrees, R&D and Gross Domestic Product (GDP) are indicators of the growing significance of this region to world science. The region's production of natural science and engineering degrees at the bachelor level was over a half a million in 1990; their doctoral degrees in these fields were over 10,000. These countries spent $91 billion, in 1987 constant purchasing power parity dollars (PPPs)[1] in overall R&D in 1990. The combined GDP of all six countries in PPPs surpassed that of the United States in the mid-eighties.

Regional Summary

These six Asian countries, which represent 77 percent of the Asian population and 42 percent of the world's population, are producing significant numbers of scientists and engineers. They produce over one-half million natural science and engineering bachelor of science degrees annually, more than twice as many as the United States. (Table 1).

Table 1 Production of B.S. degrees in science & engineering in 1990

Field	6 Asian countries	United States
Natural sciences	252,767	105,021
Engineering	261,410	64,705
Natural science & engineering	514,177	169,726
Social science	196,284	159,368
Total science & engineering	710,461	329,094
All fields	1,680,085	1,062,151

These Asian countries produce approximately equal numbers of engineering and natural science

[1] Purchasing Power Parities (PPPs) are used to convert the countries' national currency expenditures to a common currency unit that allows real international quantity comparisons to be made. PPPs are based on "market basket" pricing exercises.

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graduates at the bachelor's level.[2] The United States, with one tenth the combined population of these Asian countries, produces comparable numbers of advanced degrees and more than twice as many doctoral degrees in science and engineering. (See Table 2).

Table 2. Production of doctoral degrees in science and engineering in 1990

Field	6 Asian countries	United States
Natural sciences	6,812	11,368
Engineering	2,856	4,892
Natural science & engineering	9,668	16,260
Social science	746	6,593
Total science & engineering	10,414	22,853
All fields	19,860	36,027

However, of the approximately 22,673 doctoral degrees granted in S&E in the United States in 1990, around 3200, approximately 14 percent, were awarded to students from these six Asian countries. Tables 2 and 3 indicate that these Asian countries depend on U.S. graduate schools to educate a significant proportion of their doctoral students.[3] In 1991, the number of Asians from these countries who received S&E doctoral degrees from U.S. universities was 30 percent of the number obtained within these countries.

Table 3. Doctoral degrees in S&E granted to Asian students by U.S.universities.

1990	Acquired in U.S. university
China	940
Taiwan	906
Korea	673
India	612

[2] Natural science fields include physical, biological, environmental, agricultural, math and computer sciences. Medical sciences are not included.

[3] Ph.D.s received from other Asian countries, and in Canada and Europe, would raise the total number of degrees for these countries. Not all of these doctoral graduates of American universities from Asia return home. Percentages of those who plan to stay in the United States are given, by country, in the final section of this paper.

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Japan	73
Total	3204

Human Resources

Enrollment in Higher Education

Total university enrollments have doubled since 1975, but there are really two groups among these Asian countries: those that grew steeply in the 1950's and 1960's (India and Japan), and those that have grown in the last 15 years (Korea, Taiwan and China). See figure 1. Even with this growth, only about five percent of the college-age segment of the 2.5 billion total population are enrolled in a university. The region has a potential for extensive further growth in university education.

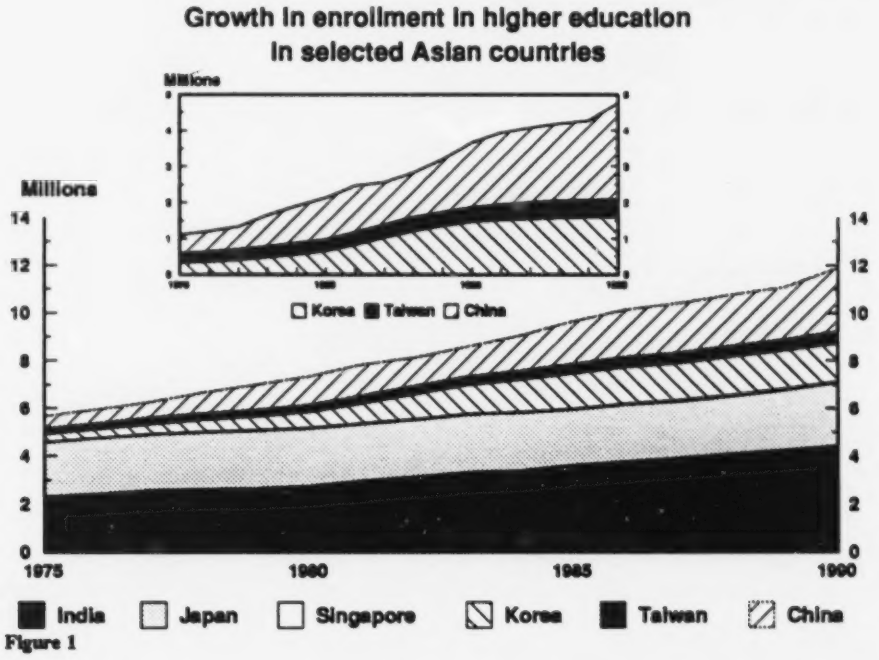


Figure 1

India accounts for more than a third of these enrollments. Singapore does not show up on the graph because of the small number of university students, relative to other Asian countries.

The number of people acquiring a university education affects the quality of the labor force and the economic development potential of a country. Within individual countries, the ratio of university students to the total 20-24 year old population varies widely, as shown in Figure 2. China is on the lower end of the spectrum. Despite impressive, massive expansion of higher education systems in the 1980s, there is still only 1.7% of China's young people in universities.

Ratio of university enrollments to the 20-24 year old population

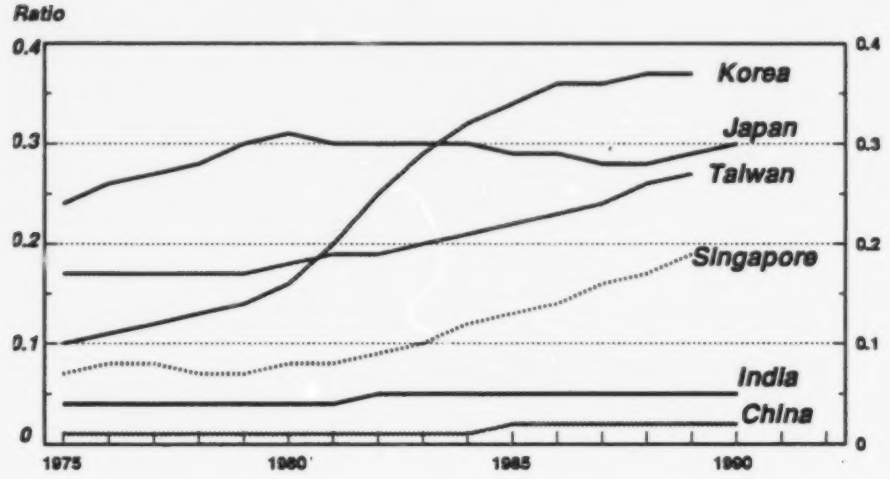


Figure 2

On the higher end of the spectrum, Korea tripled its enrollments from 1975 to the present and now has the highest proportion of its college age-group (36 percent) studying in universities, among these six Asian countries. India, with a huge growing population, maintained five percent of this age group in universities during this period. Taiwan increased from 16 to 27 percent; Japan from 24 to 29 percent.

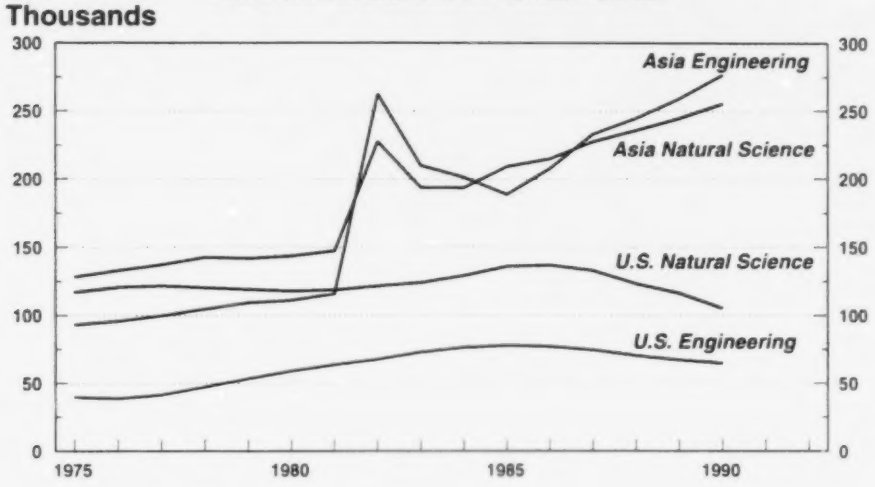
Higher Education Degree Data

Over the 15 year period, these Asian countries together have increased their annual production of bachelor degrees in natural sciences by 60 percent, and have tripled their annual production of engineering degrees. (See Figure 3). Asia's high annual number of degrees in natural sciences continues to rise as these countries attempt to go beyond "quality engineering" and low cost production to design capability, and "knowledge-based" innovative products and processes.[4] At

[4] Forthcoming Conference Report: "The Emerging Technological Trajectory of the Pacific Rim," held at the Fletcher School of Law & Diplomacy, Tufts University, Medford, Massachusetts, Oct 4-6, 1991.

the bachelor level, Asia's number of natural science degrees are equal to their engineering degrees; at the doctoral level, Asia's number of natural science degrees are three times higher than the number of engineering degrees. This proportion is similar to that found in the U.S. and Europe because careers in natural science fields often require doctoral training.

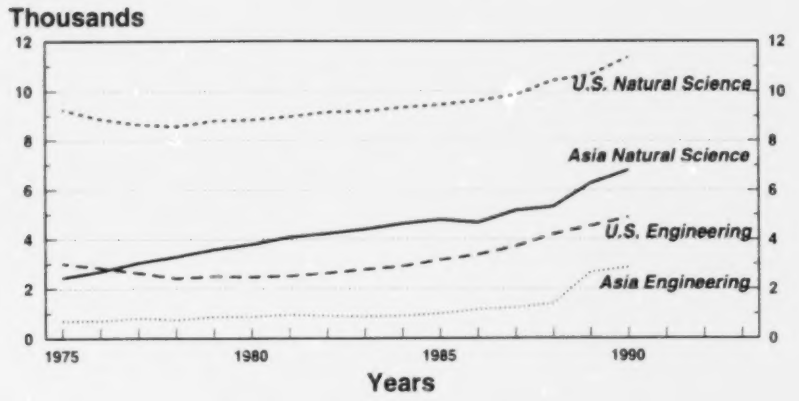
B.S. degree in natural science and engineering
Asian countries and the United States



Asian degree data include six countries:
China, India, Japan, Singapore, Korea, Taiwan
Figure 3

In the United States, the number of bachelor degrees awarded in the natural sciences remained relatively stable from 1975-1983, grew to a peak in 1985-86, and has since declined steadily in absolute numbers. The number of natural science degrees awarded in the United States has consistently been double that of U.S. engineering degrees. Within Asia, programs in China, Korea and Taiwan built up their advanced degree capability and doctoral level training in the 1980s. The jump in the doctoral degrees in Asia in 1989 (Figure 4) results from the inclusion of China in the Asia total in 1989, the first year for which doctoral degree data is available from China.

Ph.D. degrees in natural science and engineering in Asia and the United States



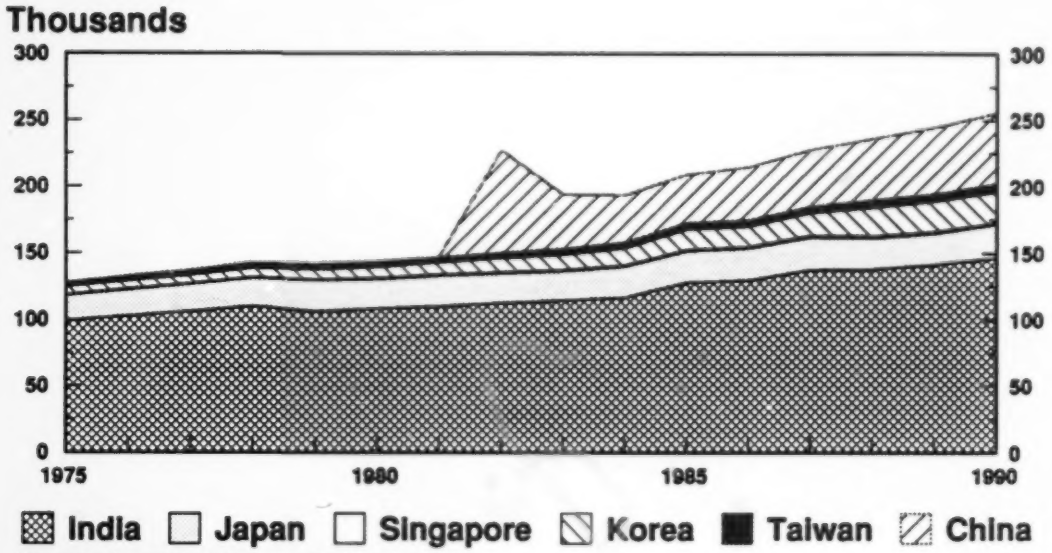
Asian degree data include six countries:
China, India, Japan, Singapore, Korea and Taiwan

Figure 4

Degrees in the Natural Sciences in Asia

India accounts for well over 50 percent of the bachelor degrees in natural sciences in Asia, as seen in Figure 5. The world's largest democracy, India is also the world's foremost educator of bachelor level and doctoral level natural scientists. India produced more bachelor degrees in natural science fields than the United States in the early 1970's, and has again surpassed the United States in natural science degrees since 1987. India and China will be the main producers of bachelor degrees in natural science for the Asian region. India, with approximately 146,000 graduates in 1990, is followed at a distance by mainland China, as the second highest producer of natural science degrees -- 52,000 graduates in 1990.

Bachelor degrees in natural science in selected Asian countries



Natural science includes physical, biological, environmental, agricultural, math and computer science.

Figure 5

The same pattern of Indian promenence in the natural sciences also occurs in advanced degrees (masters and doctorates) in Asian countries. India accounts for half of the 56,000 advanced degrees and for over half of the 6,800 doctoral degrees in natural science in the region.

Degrees in Engineering

All Asian countries are increasing their production of engineering degrees, as shown in Figure 6. China and Japan are and will be the main producers of bachelor degrees in engineering for the Asian region. China has the highest number, with 128,000 graduates in 1990.[5] Japan has the second highest production of engineers, with 81,000 graduates in that same year.

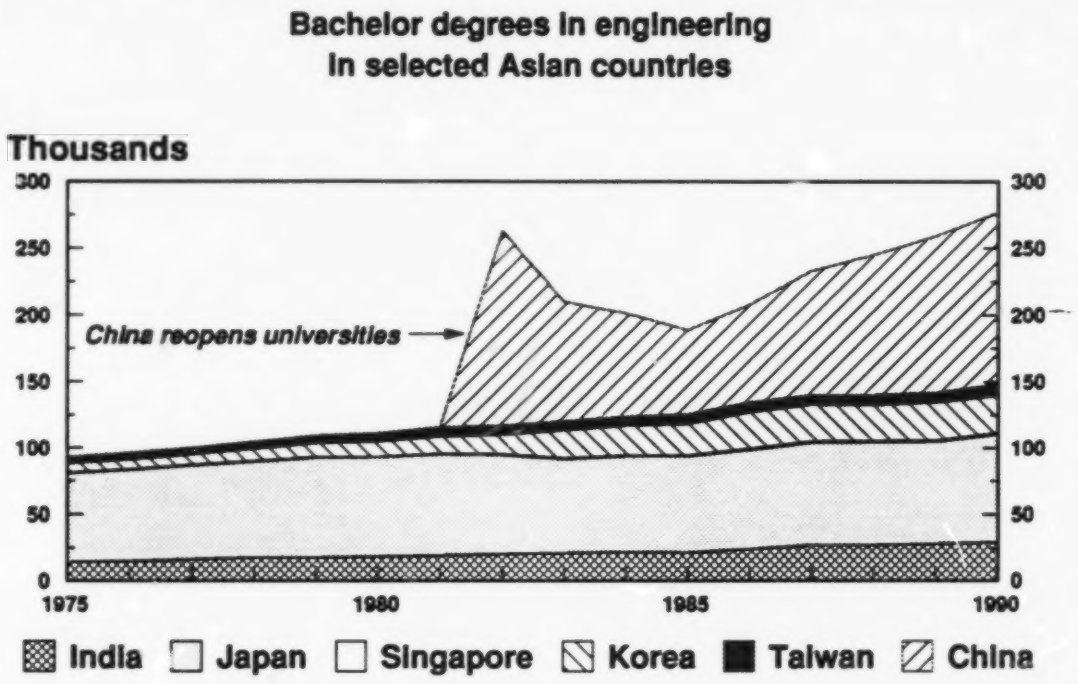


Figure 6

Rates of growth of engineering degrees differ widely across Asian countries. Japan has been producing approximately the same number of engineering graduates for over 10 years, whereas China appears to be at the beginning of a growth curve. In Korean universities, the number of engineering degrees has recently leveled off; for the past three years their engineering degrees have remained stable. Japan and Korea may be already producing as many engineering graduates as possible, given their declining college-age populations in the 1990s. They have 30-40 percent of their young people enrolled in universities and award 15-20 percent of all degrees in engineering. The same pattern of prominence of China and Japan in engineering is seen in advanced degrees, masters and doctorates.

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[5] The very high number of engineering graduates in 1982 in the China data reflect the flood of older students completing their degrees in reopened universities in the late 1970's. The number of engineering graduates then settles down and steadily increases.

Asian Foreign Students in U.S. Universities

The entire Asia region has dominated all other world regions in using the U.S. higher education and research infrastructure.[6] Asian foreign students in U.S. universities have increased from 20,000 per year in 1975 to 200,000 per year in 1989-90. In 1980, five of the ten leading countries of origin in foreign enrollment in U.S. institutions of higher education were Asian; by 1990, nine of the top ten were Asian.

Of all foreign students attending U.S. universities at the undergraduate level, 43% are Asian; and at the graduate level, 65% are Asian. Of the 33,000 Chinese students enrolled in U.S. universities in 1989-90, a large majority were enrolled in graduate programs. Similarly, the majority of Indian, Korean and Taiwanese students in the U.S. were enrolled in graduate studies, as shown in Table 4. A very large percentage of these Asian students are studying science and engineering in U.S. universities; 96 percent of Taiwanese students and 93 percent of Indian students are in S&E fields.

Table 4. Asian students in U.S. universities in natural science & engineering fields, by level

Country	# of students		% Undergraduate	% Graduate	% N.S.	% Eng
	1989-1990	1990-1991				
China	33,390	39,600	12.9%	82.7%	44.0%	20.1%
Japan	29,840	36,610	61.7	19.5	31.0	14.0
Taiwan	30,960	33,530	19.0	76.3	51.0	45.0
India	26,240	28,860	21.1	75.5	40.9	52.5
Korea	21,710	23,360	24.1	69.7	45.4	35.6
Singapore	4,440	4,500	73.2	25.0	35.0	52.0
NOTE: Percentages by level and field are estimated from 1989-1990 foreign student survey.						
SOURCE: Institute of International Education (IIE) Profiles 1989 1990						

Japan and Singapore send their students to U.S. colleges and universities mainly at the undergraduate level. Of the 30,000 Japanese students, 62 percent are enrolled in undergraduate programs, over half of which are in non-S&E fields. Students from other Asian countries, such as Hong Kong, Malaysia, and Indonesia also study in the U.S. mainly at the undergraduate level. The U.S. higher education institutions are a significant source for doctoral education of Asian students. For individual countries, the proportion of doctoral degrees obtained in the United States vary substantially, as shown in Figure 7 and the Table 5.

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[6] Open Doors, 1990-91, Report on International Educational Exchange, Institute of International Education (IIE), New York, 1991.

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Table 5. Doctoral degrees awarded within country and in the United States, 1990

Countries	Natural science Within country	Engineering Within country	Natural science U.S. university	Engineering U.S. university
China	772	1054	660 (46.1%)	280 (21.0%)
India	4600	250	311 (6.3%)	301 (54.6%)
Japan	937	948	56 (5.6%)	17 (1.8%)
Korea	399	439	343 (46.2%)	350 (44.4%)
Taiwan	104	165	446 (81.1%)	460 (73.6%)
Note: Figures in parentheses are U.S. doctoral awards as percent of the country's total doctoral degrees in that field.				

As shown, the majority of Taiwan's doctoral degrees are from the United States. About one-half of Korea's and one-third of China's are from U.S. universities. Japan obtains only a small fraction of doctoral degrees in the United States [7].

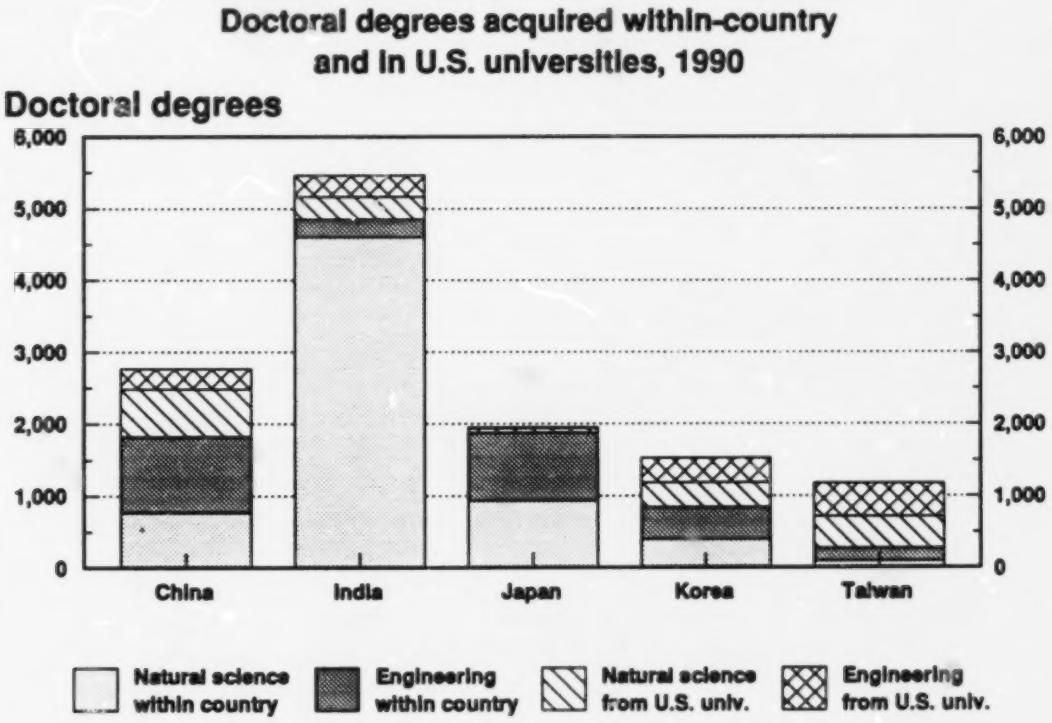


Figure 7

[7] Table 6, Citizenship of U.S. doctorates by field of science. Science and Engineering Doctorates: 1960-90. Survey of Science Resources Series, NSF 91-310. pp. 155-160.

Foreign graduate students' enrollment in U.S. universities has increased the concentration of U.S. doctoral degrees in fields of natural science and engineering. Between 1975 and 1990, the ratio of NS&E doctoral degrees to total doctoral degrees in the United States increased from 35 to 45 percent.

Participation Rates in NS&E Degrees at the Bachelor Level

Most Asian countries except Japan increased the percentage of 22-year-olds receiving NS&E degrees over the 15 year time period, as shown in Figure 8. After increasing in the 1970's and 80's, Japan's high percentage of 22 year olds obtaining NS&E degrees (six percent) fell slightly since 1987, as preferences for education in both natural science and engineering and the college-age population declined.[8]

Expansion of participation rates in NS&E degrees in selected Asian countries

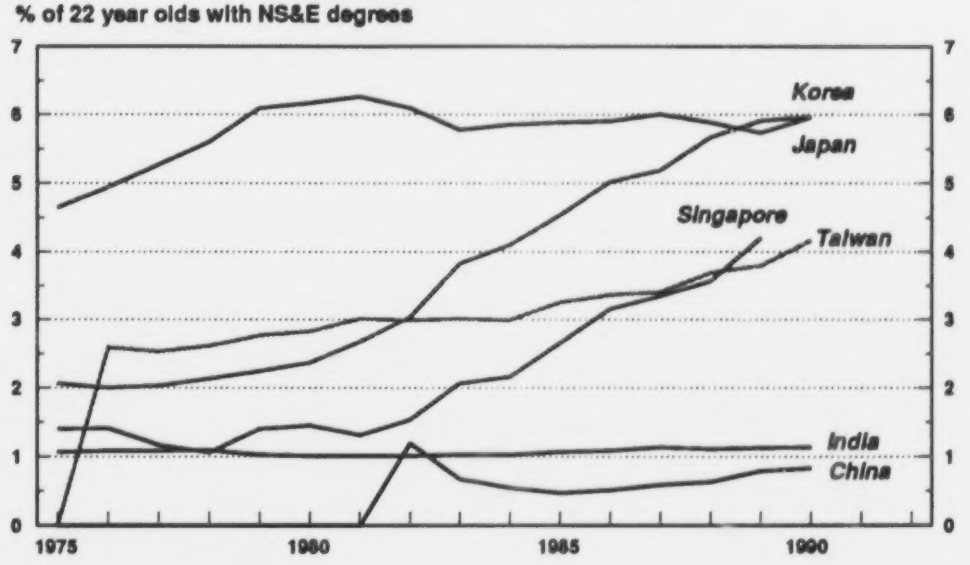


Figure 8

South Korea dramatically increased its NS&E degrees from two to six percent of its 22 year olds since 1975. Taiwan increased its NS&E degree awards from two to four percent for its 22 year old population over the last decade. China and India, with their huge populations, are

[8] Frederick S. Myers, "Where Have all Japan's Scientists Gone?" Science, Vol. 255. February 7, 1992, pp. 676-677.

maintaining their participation rates of half of one percent and 1.1 percent, respectively. If China and India continue to maintain these rates, the world stock of science and engineering graduates would be greatly augmented.

Ratio of Science and Engineering Degrees to Total Degrees

Asian universities give a higher proportion of their degrees in fields of natural science and engineering than do U.S. or European universities. Asian countries award between 25-55 percent of their university degrees in NS&E fields, as seen in Figure 9.

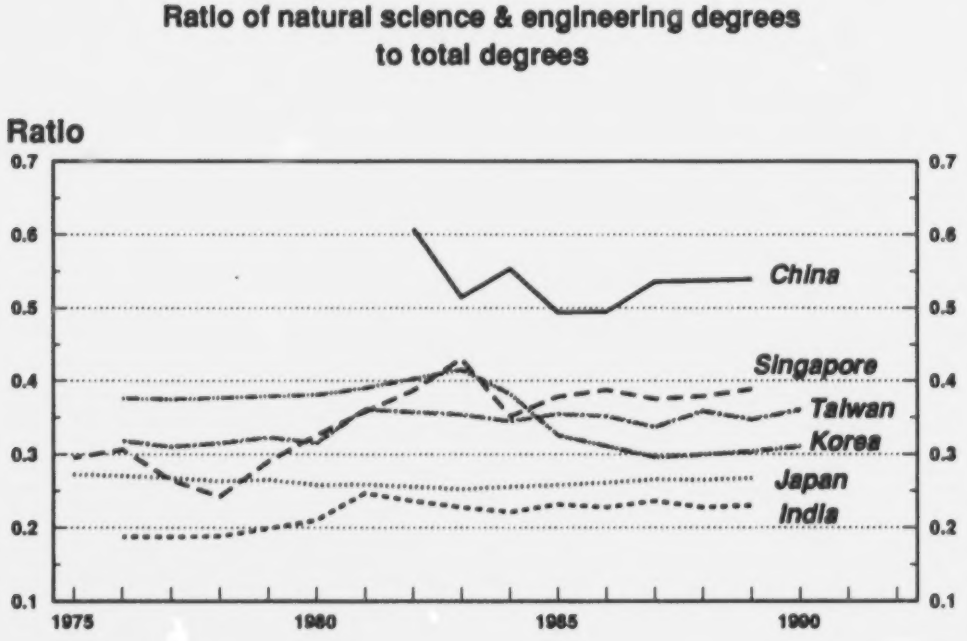


Figure 9

Asian countries (except India) especially favor engineering. Forty percent of all China's university degrees are given in engineering fields. (See Figure 10). India has a different pattern from that of the other five Asian countries. Although India has very large numbers of natural science degrees, and a high ratio of natural science degrees to total degrees, the ratio of engineering degrees to total degrees is the lowest in Asia. India's pattern is the reverse of Japan's, which has over 20 percent of its degrees in engineering, but relatively few people studying basic sciences. When social science degrees are included, Japan has the highest proportion of S&E degrees in the Asian region; close to 66 percent of all their university degrees are given in natural science, engineering, or social science. Figure 10 shows the ratios of natural science, engineering, and social science to total degrees in the six Asian countries and in the United States for the year 1990. (India does not report social science degrees).

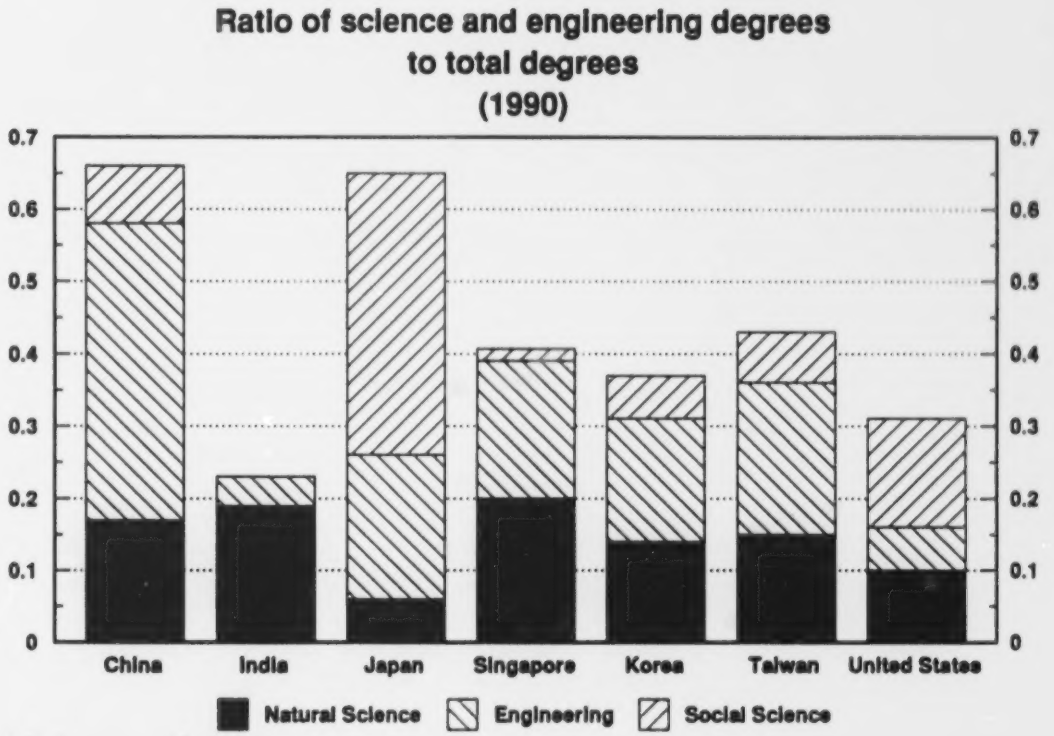


Figure 10

Demographic Changes

In the 1990's there will be decreases in the college-age population in the highly industrialized countries of the United States, Western Europe and Japan. In Japan, 18 year olds will decrease by one-half million during 1992-2000. Universities will try to attract older adults and foreign students. Japan has a "tenfold-increase policy" for foreign students, and Japan is projecting an enrollment of 100,000 foreign students by the beginning of the 21st century.[9]

However, among developing Asian countries, the college-age population of India will continue to increase and will surpass that of China after the year 2000, as shown in Figure 11.

[9] White Paper on Science and Technology 1991 (Summary). Science and Technology Agency, Japanese Government, September, 1991.

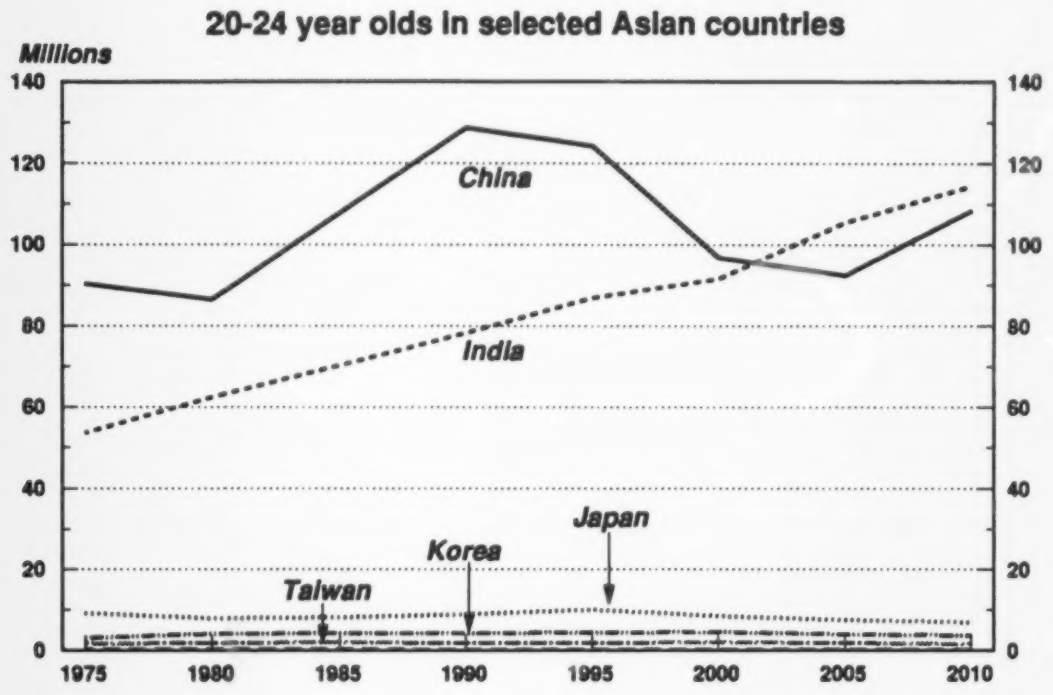


Figure 11

In the year 2000, China is expected to have 96 million young people in the 20-24 year old group; India will have 91 million. For comparison purposes, in the year 2000, Japan will have 6.9 million in the college-age population; Korea will have 3.7 million, and Taiwan two million. Western European countries will have between three and four million in their college-age populations, and the United States will have around 19 million.[10]

R&D Expenditures

In 1990, the combined R&D expenditures of these six Asian countries was approximately $91 billion in 1987 constant Purchasing Power Parity dollars ($PPP). (Throughout this paper, dollar amounts will be in 1987 constant $PPP.) Asian R&D amounts to 1.5 percent of the countries' combined GDP. In the same year, the U.S. total R&D was $130 billion, as shown in Figure 12.

[10] World Bank Population Tables, 1991

R&D in the U.S. and Asian countries
Actual 1975-90; estimated to 1992

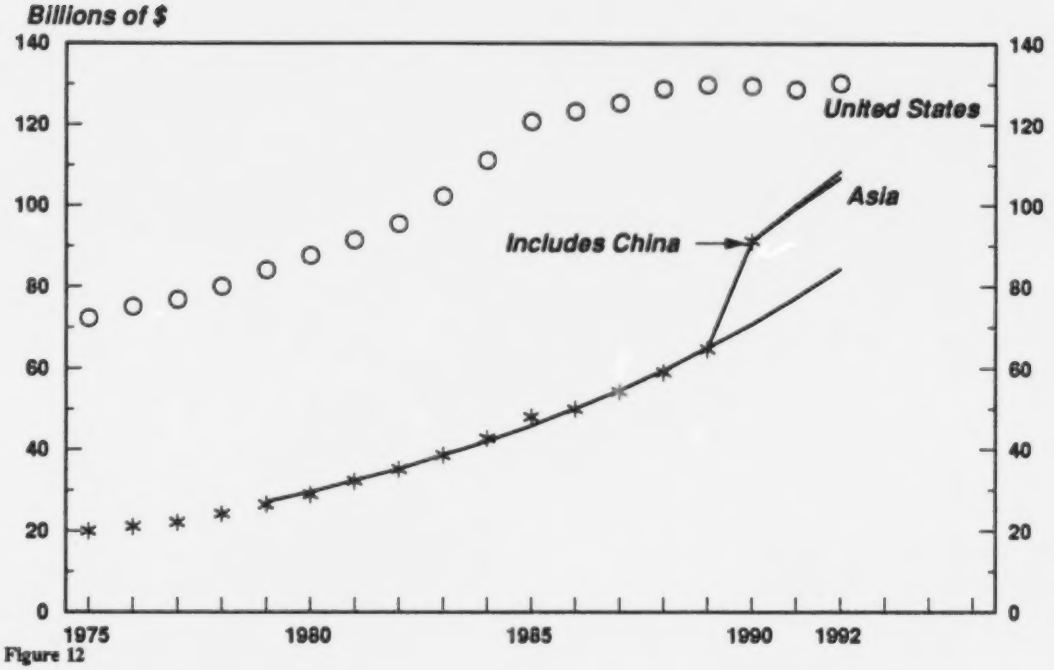


Figure 12

The growth rate of the combined R&D in five Asian countries (excluding China) was approximately nine percent between 1975-1989. China is excluded from the computed growth of Asian R&D because data from China, with a consistent definition of R&D, exists for only one year. Estimations to 1992 use this nine percent growth rate. To estimate Chinese R&D, a low growth of 2.5 percent and a high growth of six percent was assumed. Based on the past growth of nine percent, with these high and low growth estimates for Chinese R&D added, Asian R&D was estimated to 1992 (close to $110 billion), as shown in Figure 12. In 1990, the United States had 1.4 times the overall R&D investment as the six Asian countries combined, but with a lower growth rate than Asian countries. The U.S. growth rate (net after inflation) over the last six year period has been in the 1.1 percent range.

In 1990, U.S. private industries funded more R&D than the industries of the six Asian countries combined. However, industrially funded R&D in the six Asian countries is growing faster than the overall R&D, and is estimated to reach $73 billion in 1992, slightly more than the U.S. $67 billion, as shown in figure 13.

Industrially funded R&D
In the U.S. and Asian countries
Actual to 1990; estimated to 1992

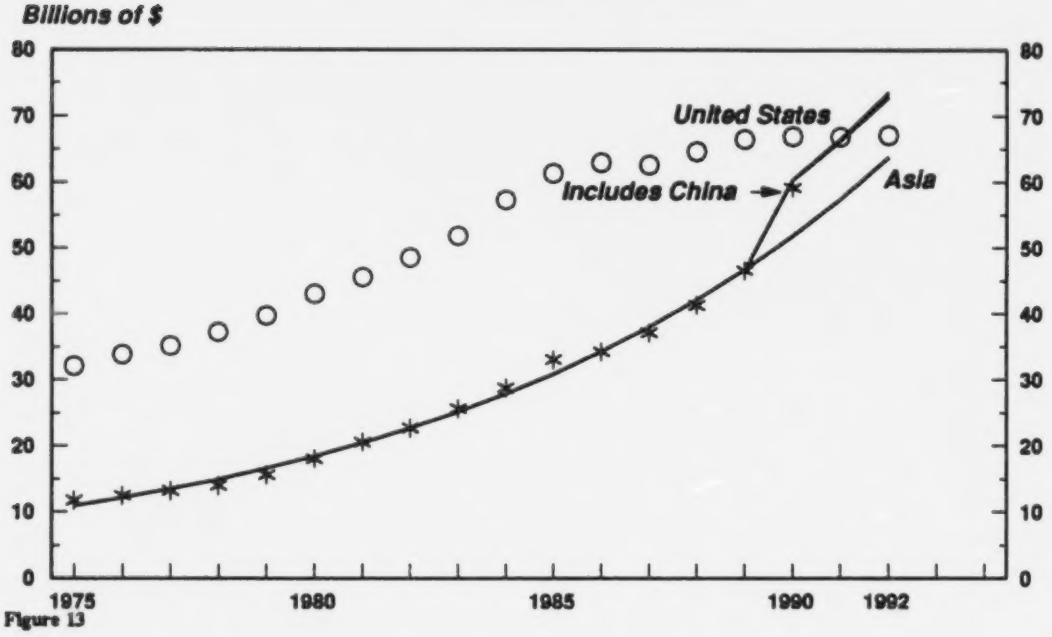


Figure 13

It is industrially funded research which is highly correlated to patents. In industrially funded R&D, U.S. growth has slowed to 1.5 percent over the last six years, down from seven percent during the previous decade.

All Asian countries in proximity to Japan, who now assemble products for labor-short Japan, would like to increase their R&D and hence the technological sophistication of their own products. Singapore, Taiwan and South Korea, as well as other ASEAN countries are establishing science parks to strenghthen indigenous R&D, attract foreign high-technology firms, and allow shared research facilities between industries and universities. Korea, Taiwan, Singapore and Hong Kong are particularly interested in joint ventures with the United States and multinationals which include technology transfer.[11]

[11] Asiapower, IEEE Spectrum Special Issue. June, 1991.

S&E Personnel

The combined sum of R&D expenditures of the six Asian countries has more than tripled over the period 1975 to 1990. The number of S&E personnel in R&D shows the same growth curve as investment in R&D, as can be seen in the following two figures, 14 and 15. The contribution of each country is shown in segmented bars. China is included only in 1990.

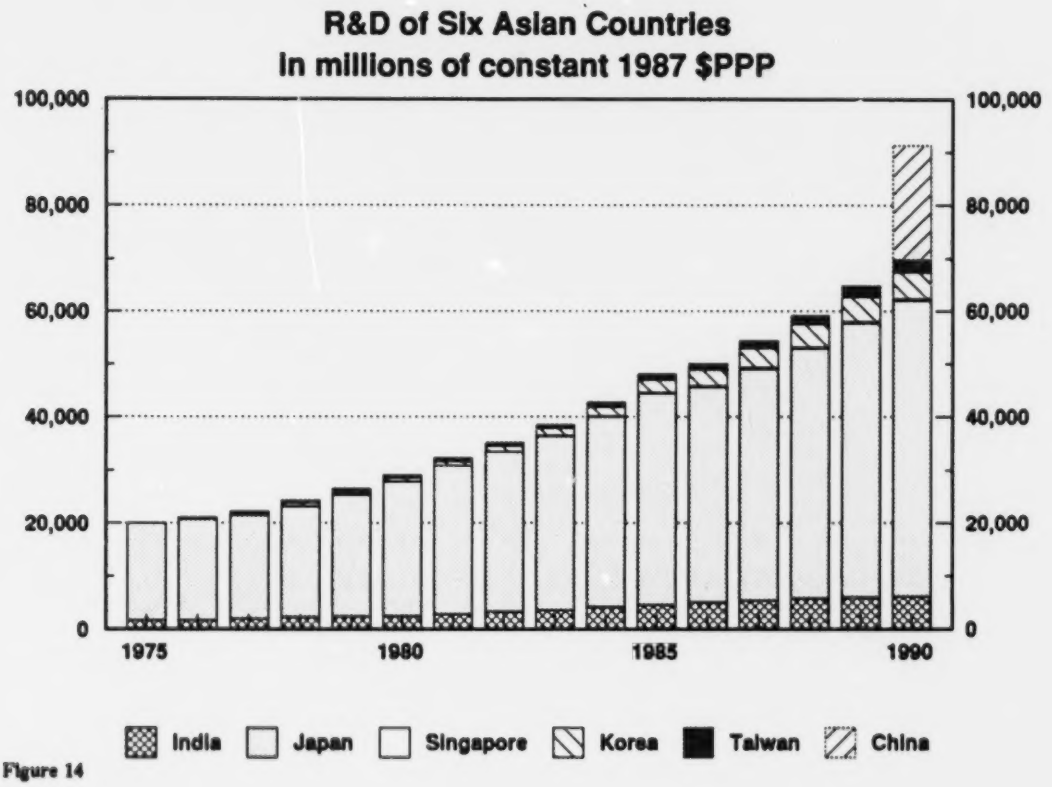


Figure 14

Asian research scientists and engineers have greatly expanded in number over the last 15 years. In 1990, with China data included, RSE numbered over one million, comparable to the numbers of research scientists and engineers in the United States.

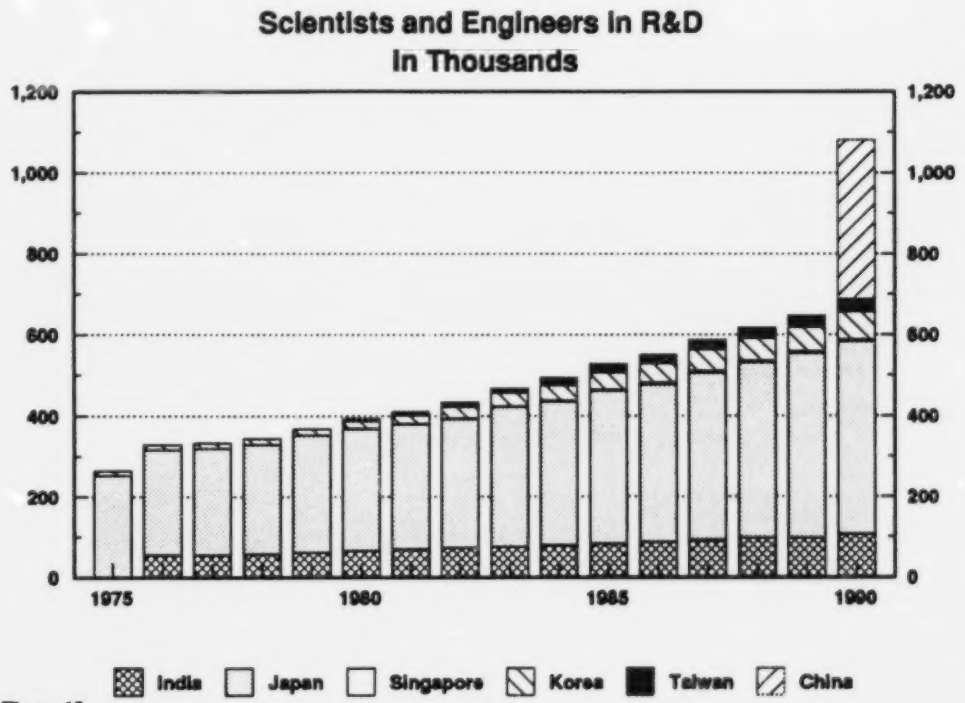

Scientists and Engineers in R&D
In Thousands
1,200
1,000
800
600
400
200
0
1975
1980
1985
1990
India
Japan
Singapore
Korea
Taiwan
China

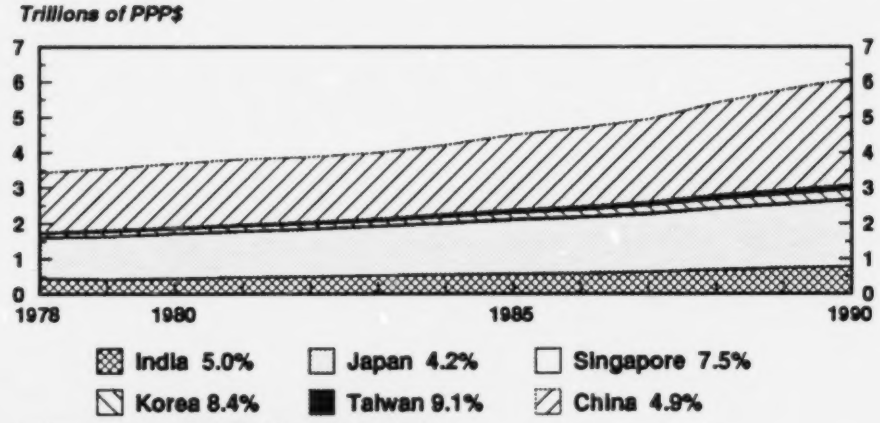
Figure 15

GDP in Six Asian Countries

These Asian countries have had the fastest growing economies in the world in the last 15 years. The following figure shows the growth in gross domestic product (GDP) for each country in purchasing power parity dollars ($PPP). (GDP using official exchange rates would be far lower for China and India.)[12]

Growth rate in gross domestic product

in selected Asian countries



China data from Statistical Yearbook of China, 1991, Japan, from OECD, other countries from the IMF, International Financial Statistics,'91.

Figure 16

The overall economic performance of a country is related to several S&T indicators. The percent of GDP invested in R&D (see Table 6) correlates with related indicators of support for S&E personnel. Asian countries fall into three groupings in their standard of living and support for R&D personnel. China and India have the lowest GDP per capita, the lowest percent of GDP in R&D, the lowest number of S&E per 10,000 of the population, and the lowest R&D investment per RSE. Singapore, Taiwan and Korea form a mid-range in these indicators. Japan has the highest GDP per capita and support for S&E personnel, approaching that of the United States.

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[12] For a discussion of this difference in China, see "A Survey of China," The Economist, November, 1992, p.4-5.

Table 6. Support for R&D and S&E Personnel by level of GDP/POP, 1990

Country	GDP/POP	R&D/GDP	S&E R&D	S&E R&D/ 10000 laborforce	R&D $ per S&E
China	$2,636	0.7%	391,100	5.6	$54,884
India	907	0.8	106,000	3.3	57,465
Singapore	10,850	0.9	4,298	30.4	67,855
Taiwan	7,193	1.7	32,145	38.2	77,032
Korea	6,342	1.9	68,831	37.2	73,297
Japan	15,296	2.9	477,866	74.9	117,068
U.S.	19,600	2.7	(89) 949,000	(89) 75.6	(89)136,800

In 1975, the U.S. GDP was somewhat larger than that of the six Asian countries combined. During the 15 year period, the positions have reversed, and the combined GDP of these six Pacific Rim countries is now somewhat larger than that of the United States.(See figure 17).

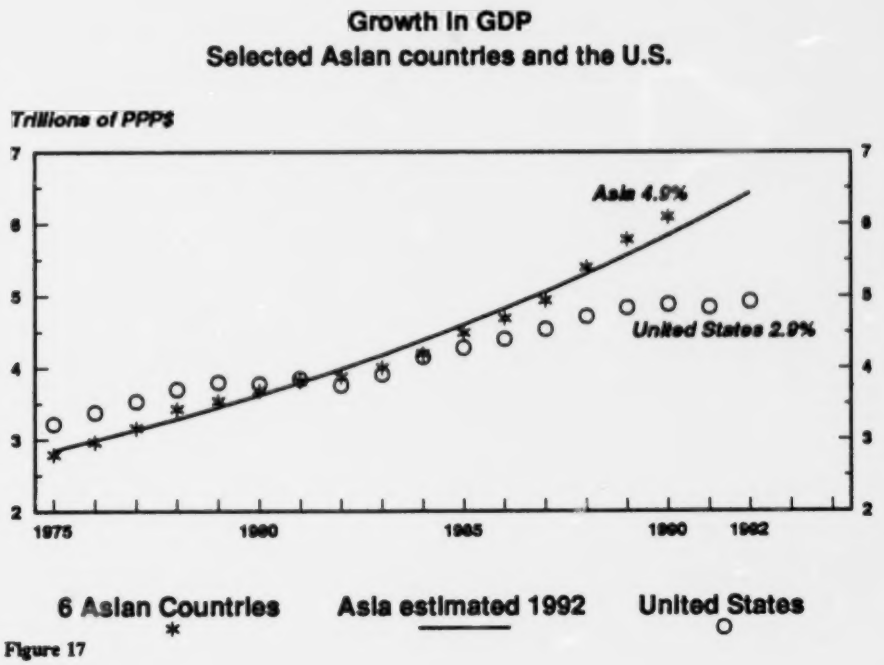


Figure 17

Human Resources by Country

These Asian countries have significant educational infrastructure and have invested heavily in its improvement to foster knowledge based strategies for economic growth and to supply highly skilled human resources in science and engineering.

China

China's extensive research infrastructure and graduate training were greatly disrupted in the late 1950's, when scholars and researchers were told to learn from the masses during the Great Leap Forward, and when universities were used for "worker-peasant-soldier-scholars" during the Cultural Revolution of the 1960's. During this period, China tripled primary school enrollments and vastly increased secondary schools. It was not until 1978, when Chinese Premier Deng Xiaoping announced that intellectual work is a form of labor, and that education and scientific research is a form of production, that higher education was again legitimized. China reinstituted entrance exams and only the very best students have been admitted to Chinese universities since then. There are over a 1,000 higher education institutes in China. Seventy of them provide four-year university programs; 43 of them, the most sought after, are comprehensive universities.

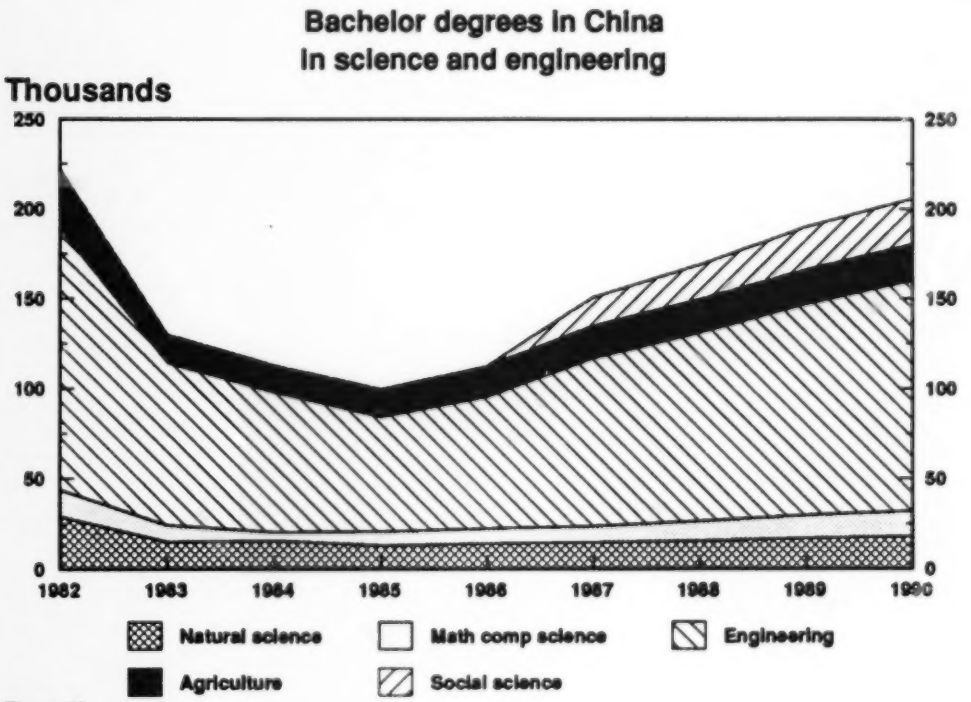


Figure 18

China is trying to upgrade the quality of domestic higher education to meet high level labor requirements. In 1988 about 86 of the higher education institutes were designated as key point

schools, singled out as centers of excellence for priority funding. The central government is financing 35,000 students for study abroad, while also increasing graduate programs to educate scientists and engineers within China so that fewer have to leave.

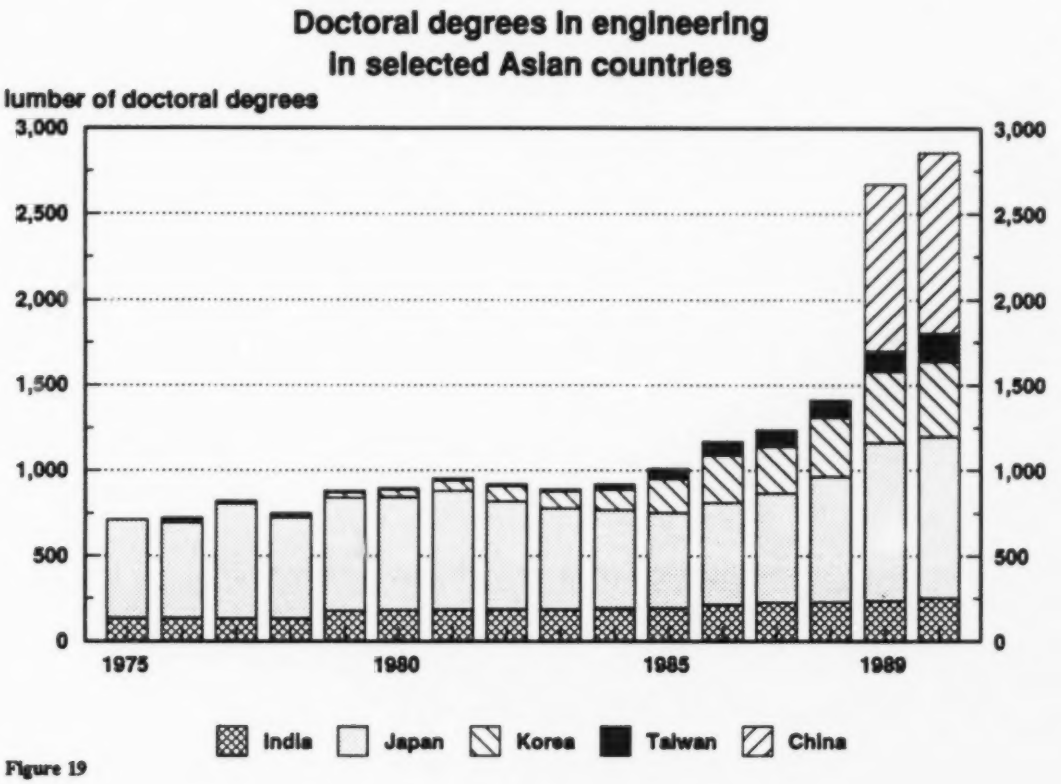


Figure 19

Data which represents internationally comparable university degrees are available for China only for the years 1982-90. The very high number of graduates in 1982, the peak in the data in Figure 18, reflects the flood of older students completing their degrees in reopened universities in the late 1970's. The number of students then declined and leveled off before beginning a steady increase starting in the mid-80s. China has the highest ratio of engineering degrees to total degrees (41 percent) in the Asian region, and produces more doctoral engineering degrees than Japan. (See Figure 19, in which China has two years of data).[13] China also has a strong committment to basic science education, and produced more than twice as many bachelor's degrees in natural sciences as Japan.

[13] China's educational statistics have doctoral degree data by field of science beginning in 1989. China does not disaggregate degree data by gender.

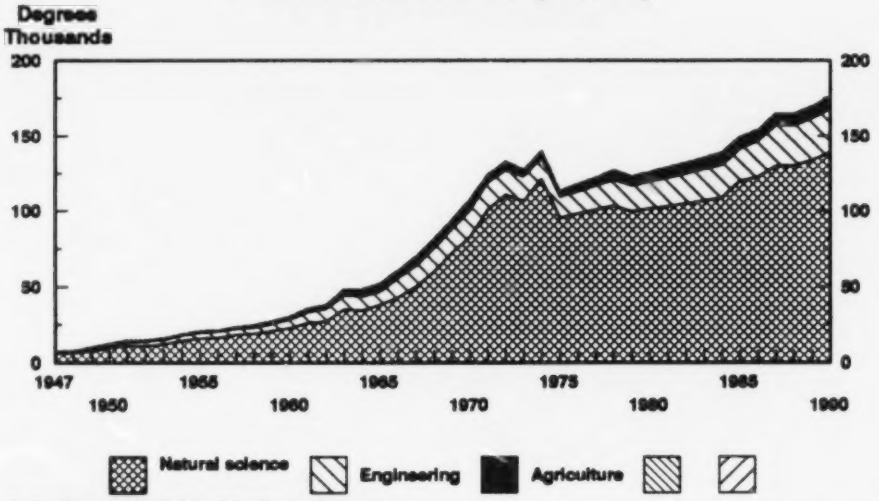
India

India, like China, has a long tradition of scholarship and respect for knowledge. India's extensive university system, which has increased in enrollments by a factor of 20 since the country's independence in 1947, was first established during the Colonial period. The first three universities created by the British administration were in Calcutta, Madras and Bombay. Several Indian scientists achieved world-wide distinction during the first half of this century. The first non-Western Nobel Laureate was an Indian, C.V. Raman, who received the prize for physics in 1931. Ten of India's top universities have 29 Centers of Advanced Study, including, along with those mentioned above, Banaras Hindu, Delhi, Punjab and the Indian Institute of Science.

In post-independence India, as well as China, science and engineering replaced civil service as the high prestige career. Government subsidies to higher education in science and engineering, parental urgings and higher salaries attracted the best students to S&E fields.

The steepest growth occurred in natural science degrees in the 1950s and 1960s; the great emphasis placed by India on natural science degrees can be seen in figure 20.

Bachelor degrees in India
in natural science and engineering



India does not report social science degrees; math is included in natural sciences, computer science in engineering.

Figure 20

This emphasis on fields of natural science results in India's scientific strengths in high energy physics, plant biochemistry, solid state and inorganic chemistry, microelectronic materials,

polymers, and ceramics. [14]

Indian Institutes of Technology (IITs), modeled after MIT, were established in the 1950's in five major cities for the study of engineering and computer sciences. They are distinguished by their extreme selectivity; every year 100,000 students take a competitive exam for 2000 seats at these Institutes. A large number of the IIT graduates continue their studies in the United States. For example, about 20 percent of Bombay IIT graduates immediately go abroad, but the proportion may be as high as 80 percent among computer science graduates.[15] It is not known how many of those who obtain graduate degrees return to India with even better qualifications.

The India bachelor degree data from 1975-1990 (Figure 20) show that engineering degrees are growing faster than science degrees, but are still rather small in number. Twenty percent of all university degrees are awarded in natural science; only four percent of all degrees are awarded in engineering. There are almost 5000 institutes of higher education (excluding junior colleges) for the arts and sciences and only 277 for engineering.

The dominance of India in the Asia region in natural sciences is also evident in advanced degrees, of which 4,600 are at the doctoral level.

About one-third of the students in all levels of university education are female: 33 percent of science students in universities are female; 7.9 percent of engineering students are female.[16]

Japan

As with India, the brief period of the last 15 years does not cover the more dramatic rise of S&E degrees. The sharp rise in Japanese enrollments and graduates in science and engineering occurred in the 1950's and 1960's. As part of the reconstruction after World War II, Japan made a concerted effort to raise the number of S&E degrees and to double its Gross National Product. Over the past ten years, Japan has educated approximately the same number of engineers, and slowly increased the number of natural science graduates. As Figure 21 shows, Japan produces a quarter of a million S&E degrees each year, but with a very small base in natural science. The

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[14] Indian Scientific Strengths: Selected Opportunities for Indo-U.S. Cooperation, Proceedings of a National Science Foundation Workshop, Washington D.C., Spring, 1987.

[15] John Maddox, "Science in India: Excellence in the Midst of Poverty," Nature Vol. 308, April 12, 1984, p. 595.

[16] University Grants Commission, in Research and Development Statistics, 1990-91. Department of Science and Technology, Delhi. Forthcoming.

majority of S&E degrees are in engineering and social science. (Business is included in social sciences in Japanese education data.)

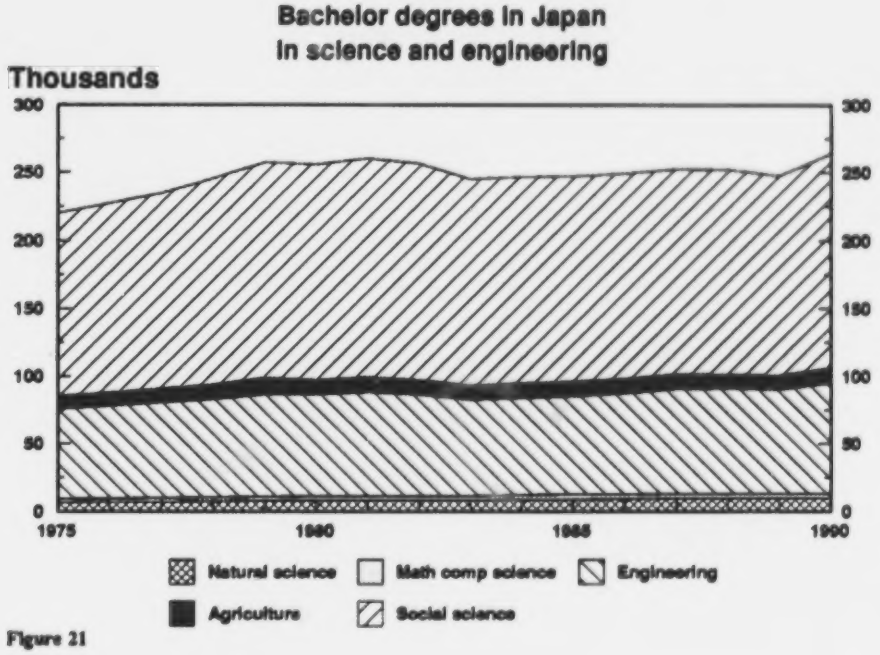

Figure 21

Private schools, many at the junior college level, make up 70% of all higher education in Japan. The Government provides 20% of the cost of private schools, and also funds 98 public universities. A small number of these public universities, the seven old imperial universities, (including the Universities of Tokyo, Osaka, and Kyoto) are the most prestigeous, with very competitive entrance examinations. Japanese private universities are very large, crowded, and far less well-equipped than the public universities,[17] so many Japanese students opt to study abroad. Sixty-one percent of the 30,000 Japanese students in the United States in 1990 were enrolled in an undergraduate degree program.[18]

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[17]David Swinbacks, "Survey pans university labs," Nature, Vol. 350, April 18, 1991, p. 544.

[18] Open Doors 1990-1991. Institute for Educational Exchange. New York, 1991.

Japan has the lowest ratio of natural science degrees to total degrees (six percent) in the Asian region. When social science is included, the ratios are very high, two-thirds of all degrees.[19] As in many other countries, there is a higher proportion of women in natural science fields than in engineering, although participation in both fields is relatively small.

Undergraduate engineering education in Japanese universities is very broad to expose students to many fields, in contrast to U.S. engineering undergraduate programs, in which students receive more in-depth education in specialized fields. Japanese companies prefer to provide extensive in-house training to young engineers, instead of hiring older students with a masters or doctoral degree from Japanese universities.[20] Since advanced degrees have not traditionally conferred employment benefits on those who earn them, there have been relatively few advanced degrees in Japan.

Recently however, there has been growth in advanced S&E degrees in Japan, particularly in 1991. With the goal of increasing basic research, Japan's S&T policy statements call for a strengthening of Japan's graduate education, increased financial assistance, and research funds for doctoral students.[21]

One example of Japan's attempt to improve graduate education is the establishment of the Research Center for Advanced S&T at the University of Tokyo. The Tokyo Institute of Technology (TIT) is also attracting foreign graduate students. Japan recruits the best engineering students from all over Asia and gives them scholarships for masters and doctoral programs at the University of Tokyo. Recruitment includes all the Indian Institutes of Technology (IITs), Chinese universities in Peking and Shanghai, as well as universities in Pakistan, Bangladesh, Thailand, Indonesia, and Sri Lanka. Doctoral programs are given in English and generous scholarships, available only to foreign students, are considered an investment. It is assumed that later these graduates will play the role of a bridge between the business of their countries and Japan. The Monbusho scholarships for doctoral programs add another five years after the doctorate for the foreign students to visit their major professor.[22]

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[19] In Japan's educational statistics, social science degrees include economics and business degrees combined.

[20]Kouichi Hyodo, "Corporate In-House Training Program for Toshiba Engineers," presented at the PECC Workshop on Integrating Technology & Management, Indonesia, Nov., 1992.

[21] "Revised General Guidelines for Science and Technology Policy," Government of Japan, Cabinet Decision, April 24, 1992. English translation provided by NSF Tokyo Office. Report Memorandum #230.

[22] Dr. Fumio Nishino, Department of Civil Engineering, University of Tokyo, personnal communication, PECC Conference, Indonesia, Nov., 1992.

Singapore

Singapore has achieved remarkable economic growth because of its strategic emphasis on, and effective policies for, the development of human resources and supporting S&T infrastructure. In the 1960's, Singapore began to attract multinational corporations, and embarked on a massive program in industrial training to upgrade the skill levels of workers and increase the supply of technicians and engineers. As the economy has developed, tertiary education has expanded through two polytechnics and the national university, emphasizing natural science and engineering. (See figure 22). In the 1990s, the emphasis is on attracting high-tech, knowledge-intensive industries, and in internationalizing its own local firms.

Singapore has invested heavily in the National University of Singapore to supply highly skilled scientists and engineers. More than 32 percent of the micro-state's R&D is performed by the University; 40 percent of R&D personnel are in the university. In addition, Singapore greatly expanded overseas education.

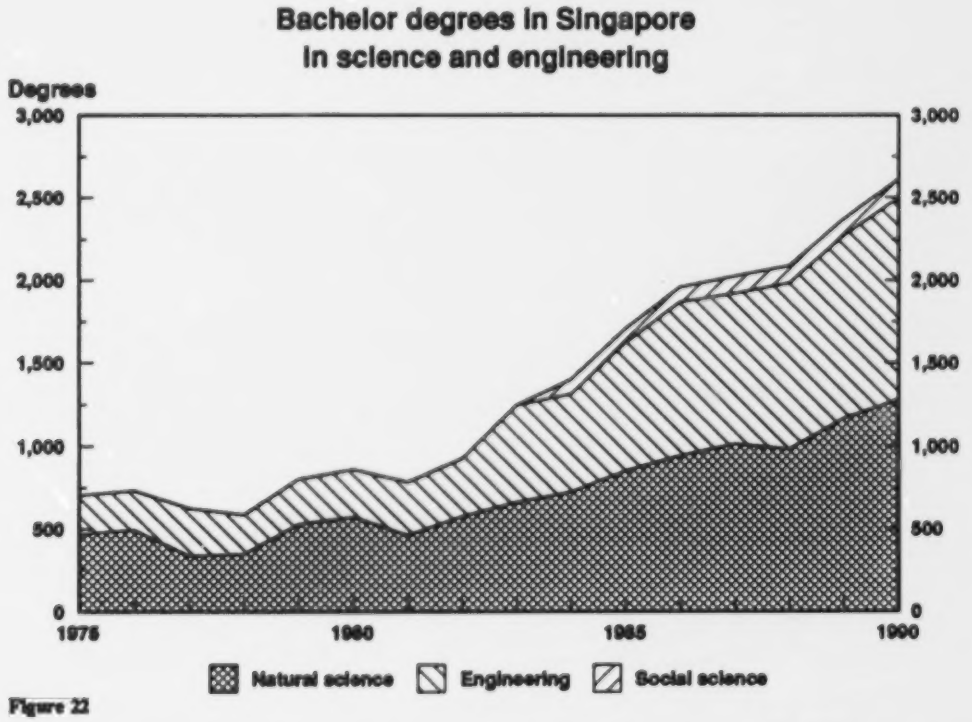

Figure 22

Gradually, Singapore has phased out labor-intensive industry through a high-wage policy. In recent years, the training has shifted to produce a highly specialized professional labor force, especially in the information-technology related industry. Singapore's graduate education has expanded programs in systems science, microelectronics, advanced computer communications, and computer-integrated manufacturing.

South Korea

South Korea, like many countries in Asia, has aspired to promote coherent and self-sustained development through education. Korea emphasizes S&E education through special scholarships, exemption from military service and rewarding employment. The Government's decision to double admission's quotas in 1980 was an attempt to keep up with industry's demand for engineers, computer scientists and other specialists. New local area colleges had to be added to existing universities to ease the strain on laboratories and computer facilities. Figure 23 shows the five-fold increase in natural science and engineering degrees over the last 15 years.

Bachelor degrees in Korea in science and engineering

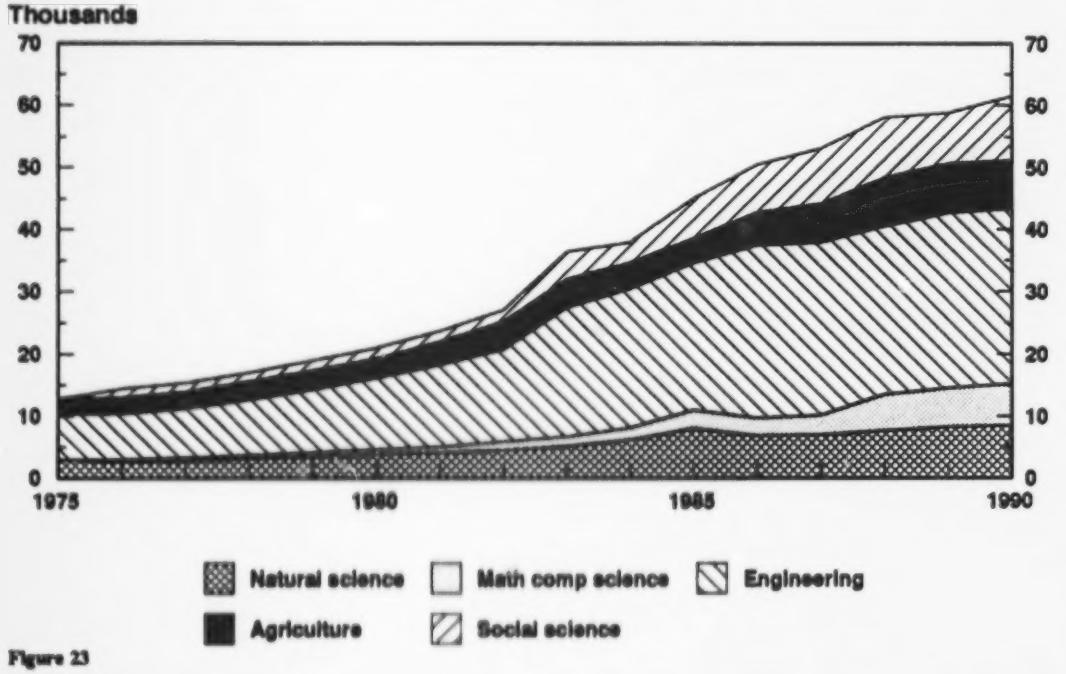

Figure 23

The most prestigious Korean universities are those older ones that survived under Japanese occupation from 1905-45. Science and engineering graduates from these prestigious universities are preferred by major industries. The Korean Advanced Institute of Science and Technology (KAIST) was established to identify gifted students in science, increase support for post-graduate training locally and to strengthen research capacity. KAIST, along with the Ministry of Science and Technology (MOST), runs an undergraduate institute for talented students who win national science scholarships. The Government is again considering doubling enrollments in engineering departments. The current S&T policy states that university advanced degrees will be linked with industrial demands through joint research projects.

In Korea, women and men have almost the same ratio of natural science degrees to total degrees. The proportion of women receiving natural science degrees is higher than in Japan. As in many other countries, the ratio of engineering degrees to total degrees is far lower for women than for the overall student population.

Overall, South Korea has the highest participation of females in natural science and engineering degrees among the three Asian countries shown in figure 24. Although female participation improved slightly in these Asian countries between 1985 and 1990, both female and total 22-year-old participation in NS&E degrees declined in the United States.

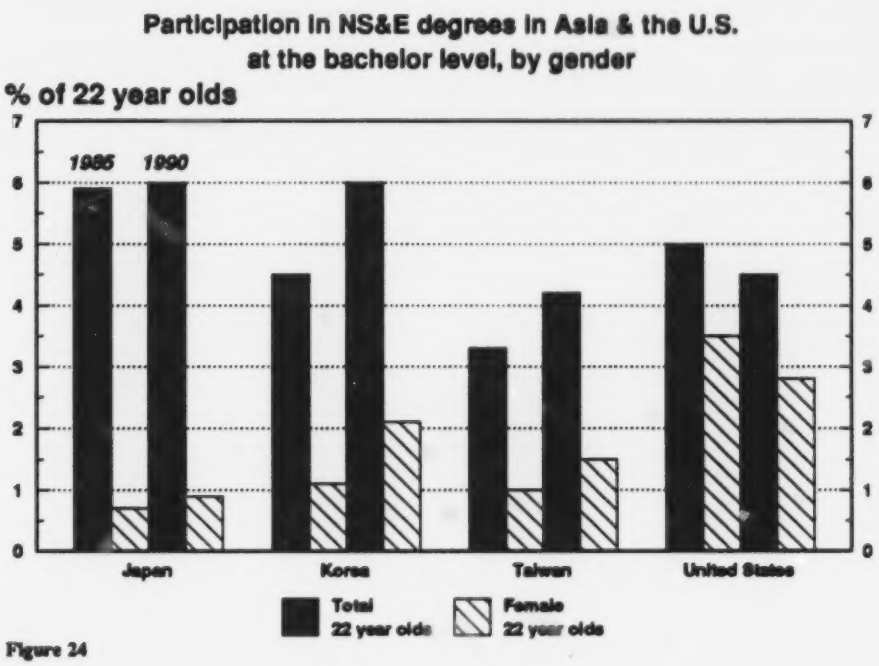

Figure 24

South Korean graduate education is expanding rapidly to overcome the shortage of high-level personnel trained beyond the bachelor's level. Whereas there were only 800 masters and doctorate recipients from natural science and engineering faculties in 1976, by 1990 there were 8000, with 900 doctoral degrees.

To further upgrade the labor force, the government is expanding programs to send students abroad. The Korea Science and Engineering Foundation (KOSEF) has an enlarged scholarship program to allow some 10,000 science and engineering students to receive post-doctoral training abroad by the year 2000. In addition, the government is attracting Korean scientists and engineers abroad back to Korea, as salaries and living and working conditions have improved in Korea.

Taiwan

Taiwan, like Korea, controls enrollments in higher education and emphasizes engineering (33 percent of all university students). Their expansion of science and engineering education over the last 15 years is shown in Figure 25.

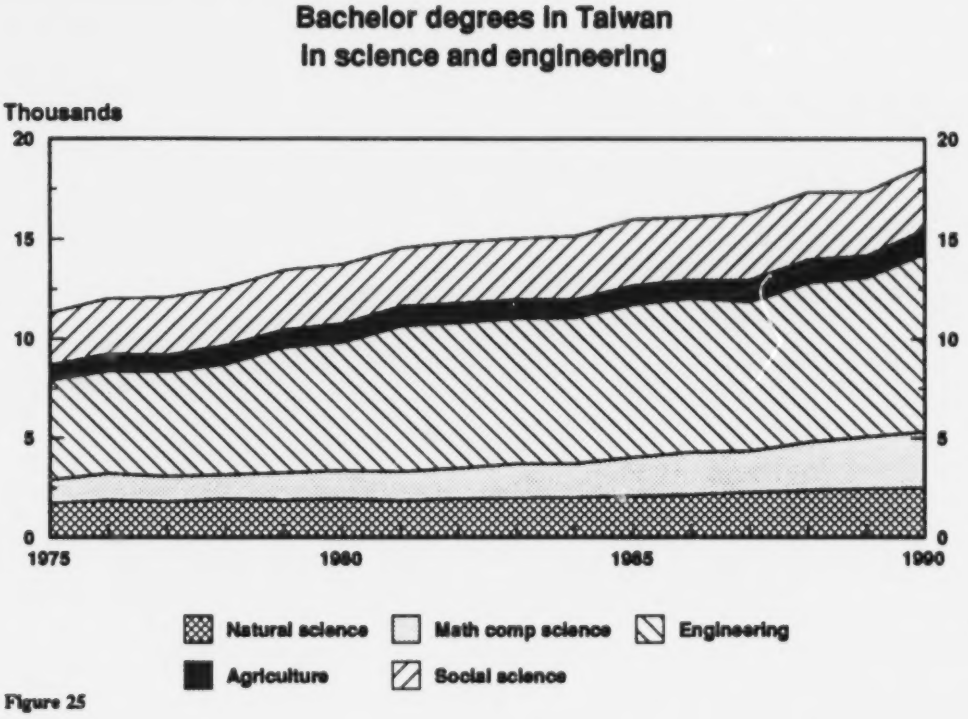

Figure 25

There are limited opportunities for graduate study in Taiwan, so students mainly study abroad for advanced degrees. The United States provides approximately 77 percent of Taiwan's doctoral degrees in natural science and engineering.

Female participation in NS&E degrees in higher education in Taiwan has gone from one to one and one-half of the 22 year old female population in the last five years. Of the female university degrees, about 25 percent are in the sciences and engineering.

Needs for further research

Attention should be given to the interrelationships between Asian S&T capacity and higher education training in other countries, especially the United States. How much of a role do Asian-born U.S.-trained scientists who are working in the United States play in Asian S&T development? Further study should also explore mobility among these Asian countries for graduate degrees in S&E and research employment in industry, government institutes and universities. In 1991, Japan received 41,000 students from the Asia region for university and advanced education, the United States about 230,000. Further research is needed on how Japan is changing in the region to make its universities accessible and to transfer technology and engage in cooperative technology development. The extent to which Japan will look to China, India and Russia for tapping the S&E pool would be interesting to follow.

Implications for the United States

1. These Asian countries will continue to use the U.S. higher education system. The sharp jump in the value of Asian currencies relative to the dollar has greatly increased the number of Asian students with the financial capacity to study in the United States, and will continue to do so. Their continued expansion of graduate education in science and engineering does not decrease their need for overseas study. China has begun a "self-reliant" effort to educate doctoral students within China, possibly because the majority educated in the United States remain here. (See Table 8) However, the need for foreign and domestic education grow together.[23] These Asian countries cannot meet all the demand for higher education fast enough nor can they staff new or expanded domestic institutions without graduate training abroad, often in the United States.

2. Foreign graduate student enrollment in U.S. universities and preference for natural science and engineering (NS&E) degrees will maintain U.S. doctoral programs' strong emphasis on NS&E. Foreign graduate student enrollment in U.S. universities has strengthened the focus of U.S. doctoral programs on natural science and engineering. Over the 16 year period, 1975-1990, the ratio of NS&E degrees to total doctoral degrees in the United States has increased from 35 to 45 percent.

3. These Asian countries will begin to challenge the United States for the S&T personnel educated in U.S. universities for their own high-technology economies. Asians have accounted for more than half of all scientists and engineers immigrating to the United States between 1970 and 1985.[24] In 1988, about 36,000 Asian scientists and engineers were certified by the U.S. Department of Labor. It may be twice as many receiving entry by relatives rather than certification who eventually work as scientists and engineers in the U.S. laborforce. In 1991, over 2600 new Asian doctorates in science and engineering from U.S. universities planned to stay

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[23] William Cummings, "Global Trends in Overseas Study," IIE Report, forthcoming, 1992.

[24] Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook, Survey of Science Resources Series, National Science Foundation, NSF 86-305.

in the United States (See Table 8.)

However, since the Asia region will be an economically and scientifically important area needing S&E personnel, these Asian countries will make attractive offers to have their students return after academic and industrial experience in the United States.[25] Taiwan and Korea have been particularly successful in attracting them to return, offering large incentives to start companies in critical technologies. (See Table 8 on the decreasing percentage of Taiwanese and Koreans who plan to stay in the United States.)

4. Continued linkage with these Asian scientists and engineers trained in the United States through international S&T collaboration would foster a free flow of RSE personnel between the East and West. U.S. trained Asian scientists and engineers are our natural counterparts in international collaboration.[26]

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[25] Paul Pedersen, et.al., "The Reentry of U.S. Educated Scientists and Engineers to Taiwan: An International Cooperative Research Project," Supported by NSF Grant # INT-8420095 and a grant from the National Science Council of the Republic of China.

[26] For areas of scientific excellence in Asia, see the quarterly publication, Scientific Information Bulletin of the Office of Naval Research, Asian Office, Unit 45002, APO AP 96337-007. The Tokyo Office of the National Science Foundation has reports available on STIS, NSF's on-line Science and Technology Information System.

Table 8. Asian doctoral recipients in natural science and engineering from U.S. universities who plan to stay in the United States: 1980, 1990, and 1991

Country	Total [1]	Plan to stay [2]		Firm plans to stay [3]	
		Number	Percentage	Number	Percentage
		1980			
China [4]	280	157	56.1	131	46.8
India	339	248	73.2	201	59.3
Japan	47	19	40.4	13	27.7
South Korea	87	51	58.6	44	50.6
Taiwan	399	255	63.9	214	53.6
Total	1,152	730	63.4	603	52.3
		1990			
China	964	585	60.7	413	42.8
India	630	430	68.3	341	54.1
Japan	75	36	48.0	29	38.7
South Korea	766	271	35.4	200	26.1
Taiwan	931	428	46.0	287	30.8
Total	3,366	1,750	52.0	1,270	37.7
		1991			
China	1,520	1,265	83.2	778	51.2
India	633	496	78.4	364	57.5
Japan	73	32	43.8	23	31.5
South Korea	827	334	40.4	209	25.3
Taiwan	981	539	54.9	313	31.9
Total	4,034	2,666	66.1	1,687	41.8

(1) Total doctoral recipients in natural science and engineering
(2) Doctoral recipients who think they will locate in the United States
(3) Doctoral recipients who have postdoctoral research appointments or academic, industrial, or other firm employment in the United States
(4) China data are for 1987, the earliest year for which data are available.

SOURCE: National Research Council 1992

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